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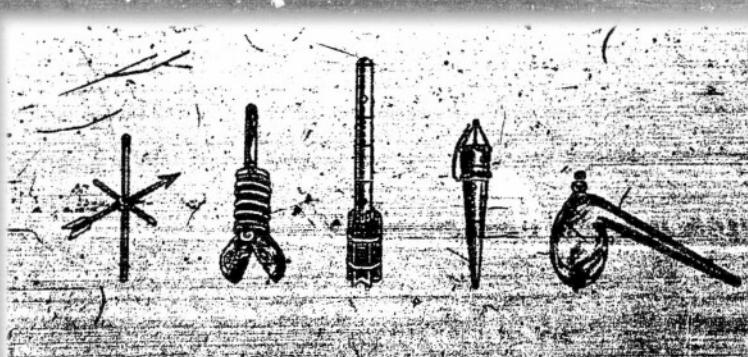
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Depth of The Motionless Layer
In The Gulf of Mexico

Richard M. Adams

Research Conducted through the
Texas A. & M. Research Foundation
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THE AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
Department of Oceanography
College Station, Texas

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Project 24

DEPTH OF THE MOTIONLESS LAYER
IN THE GULF OF MEXICO

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Report prepared January 6, 1954
by
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TABLE OF CONTENTS

	Page
Abstract	
Introduction.....	1
Source of Data.....	1
Defant's Method.....	1
Hidaka's Method.....	3
Comparison of Results.....	4
Plans for Future Work.....	5
Acknowledgements.....	6
Figures	
Distribution List	

DEPTH OF THE MOTIONLESS LAYER
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Richard M. Adams

Abstract

The methods of Defant and Hidaka have been used in this study of the depth of the motionless layer in the Gulf of Mexico. Data used in the study were obtained on Cruises 1, 2 and 3 of the U. S. Fish and Wildlife Service vessel ALASKA. The results of the two methods are shown pictorially in order to facilitate comparison. A comparison is also made with results obtained by Dietrich who employed the method of depth of minimum oxygen content.

DEPTH OF THE MOTIONLESS LAYER
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1. Introduction. In the following report, the results of two methods for determining the depth of no motion in the Gulf of Mexico are presented. No effort is made at this time to support or criticize either method since it is felt that the amount of data upon which these studies were based is too small to warrant the drawing of definite conclusions. However, comparison of the results of these methods is of interest.

2. Source of Data. In 1951, personnel of this project working in cooperation with the U. S. Fish and Wildlife Service of Galveston, Texas, completed three cruises in the Gulf of Mexico using the Fish and Wildlife vessel ALASKA. These cruises were planned to give a complete coverage of the Gulf. The three cruise plans, showing stations occupied successfully, are shown in Figure 1. Stations were normally spaced at forty mile intervals with exceptions being in the Straits of Florida and the Yucatan Channel where they were spaced at approximately twenty mile intervals.

Cruise 1 included the central Gulf, Straits of Florida and the Yucatan Channel. Cruise 2 covered the western Gulf from Longitude 92°W to the Texas-Mexico coast. Unfortunately, a period of rough weather caused the omission of four important stations along Longitude 92°W. Cruise 3 covered the northeastern portion of the Gulf.

3. Defant's Method. Defant has shown (1941) that in the Atlantic Ocean the anomaly of the dynamic depth interval between isobaric surfaces remains nearly constant within certain depth intervals. He has

assumed that surfaces of no motion lie somewhere within these intervals.

In using this method for the Gulf of Mexico data mentioned above, comparisons were made for pairs of stations along each line of stations. The differences between the dynamic depth anomalies from the surface to each standard pressure surface were computed as shown in Table 1, where stations 3 and 4 of Cruise 3 are compared as an example.

Table 1. Computation of differences between the dynamic depth anomalies from the surface to each standard pressure surface for stations 3 and 4, Cruise 3.

Pressure (Decibars)	ΔD_3 (Dynamic meters)	ΔD_4 (Dynamic meters)	$\Delta D_3 - \Delta D_4$ (Dynamic meters)
0	0.000	0.000	0.000
10	.093	.055	.038
20	.142	.106	.042
30	.194	.153	.041
50	.265	.236	.029
75	.333	.318	.015
100	.390	.382	.008
150	.482	.481	.001
200	.552	.560	-.008
250	.614	.629	-.015
300	.672	.691	-.019
400	.777	.804	-.027
500	.871	.903	-.032
600	.955	.993	-.038
700	1.031	1.073	-.042
800	1.100	1.146	-.046
1000	1.219	1.264	-.045
1200	1.323	1.358	-.035

These differences were then plotted against depth (see Figure 2 for example) to ascertain at what depth intervals the anomaly of distance between isobaric surfaces remained most nearly constant. After such intervals were chosen, the assumption was made that a motionless surface

existed at the midpoint of such intervals. Thus in our example (Table 1, Figure 2), the depth of the motionless surface was assumed to be at 900 m., corresponding to a pressure of 900 decibars.

Similar computations were made for all other pairs of stations. The value obtained for each pair of stations was plotted on a base map of the Gulf midway between the pair of stations, and contours drawn. (Figure 3)

4. Hidaka's Method. In 1949, Dr. Koji Hidaka presented a method for determining the depth of the motionless layer (Transactions, American Geophysical Union, Vol. 30, Num. 3) from a consideration of the distribution of salinity. In brief, this method is based on the differential equation governing the distribution of salinity in sea water, that is

$$\frac{\partial S}{\partial t} + \mu_x \frac{\partial S}{\partial x} + \mu_y \frac{\partial S}{\partial y} + \mu_z \frac{\partial S}{\partial z} = k_x \frac{\partial^2 S}{\partial x^2} + k_y \frac{\partial^2 S}{\partial y^2} + k_z \frac{\partial^2 S}{\partial z^2} \quad (1)$$

where S represents salinity, t is time, μ_x , μ_y , and μ_z the x , y and z components of current velocity, and k_x , k_y and k_z the coefficients of diffusion in the x , y and z directions. In a motionless layer, $\mu_x = \mu_y = \mu_z = 0$ and $\frac{\partial S}{\partial t} = 0$ so that (1) becomes

$$k_x \frac{\partial^2 S}{\partial x^2} + k_y \frac{\partial^2 S}{\partial y^2} + k_z \frac{\partial^2 S}{\partial z^2} = 0. \quad (2)$$

In our study in the Gulf of Mexico we have assumed that vertical mixing prevails so that the first two terms of (2) can be neglected. Thus we

need only to consider

$$\frac{\partial^2 S}{\partial z^2} = 0.$$

Using the salinities at standard depths for all stations shown in Figure 1, and the relationship

$$\frac{\partial^2 S}{\partial z^2} = \frac{S_{i-1} + S_{i+1} - 2S_i}{(\Delta h)^2}$$

where S_i is the salinity of the level in question and S_{i-1} and S_{i+1} are the salinities at a distance Δh above and below the level of S_i , values of $\frac{\partial^2 S}{\partial z^2}$ were computed for each standard depth. The point at which $\frac{\partial^2 S}{\partial z^2}$ vanishes was then considered to be the depth of the motionless surface. These depths were plotted at the various station positions and contours drawn as shown in Figure 4.

5. Comparison of Results. A comparison of the results of the methods described above is of interest. It will be noted that with Defant's method, two maxima are obtained, one in the western Gulf and one in the east central Gulf. These maxima also appear in Hidaka's method but both are displaced and are of different magnitudes. The western Gulf maximum in Figure 3 is found to the southeast in Figure 4 with the latter being about 300 m. greater than the former. The east central maximum in Figure 3 is again displaced to the southeast in Figure 4, but in this case the latter is about 600 m. smaller than the former. Both methods show a variation in depth of the motionless layer of from

200 to greater than 1000 m. Moreover, the methods show good agreement in the area of the Yucatan Channel and fair agreement in the Straits of Florida.

In 1936, Dietrich published a chart showing the depth of the motionless surface in the Gulf as inferred from the depth of minimum oxygen content. This method also shows two maxima, one in the western Gulf and one in the east central Gulf, both very close to the positions of the maxima obtained by Defant's method. However, Dietrich's western maximum was at a depth of 400 m. while the east central maximum was at a depth of 600 m. Dietrich's values ranged from 200 to 600 m. They were larger in the Yucatan Channel than the values obtained by using the methods of Defant and Midaka. They were also larger in the Straits of Florida than the values obtained using Midaka's method but compared quite favorably in this area with results of the Defant method.

6. Plans for Future Work. As more data become available, it will be possible to study in greater detail the above methods for determining the depth of the motionless layer. More immediately, however, it is planned to check the methods of Defant and Midaka for mass transport across one or more sections of the Gulf. This, it is hoped, will furnish us with a possible check for one of the methods.

7. Acknowledgements. This work was initiated at the suggestion of Dr. Koji Hidaka who is also the originator of one of the methods used. Mr. Robert O. Reid offered many valuable suggestions in regard to possible future work. Personnel of Project 24 assisted with the computations, typing and drafting.

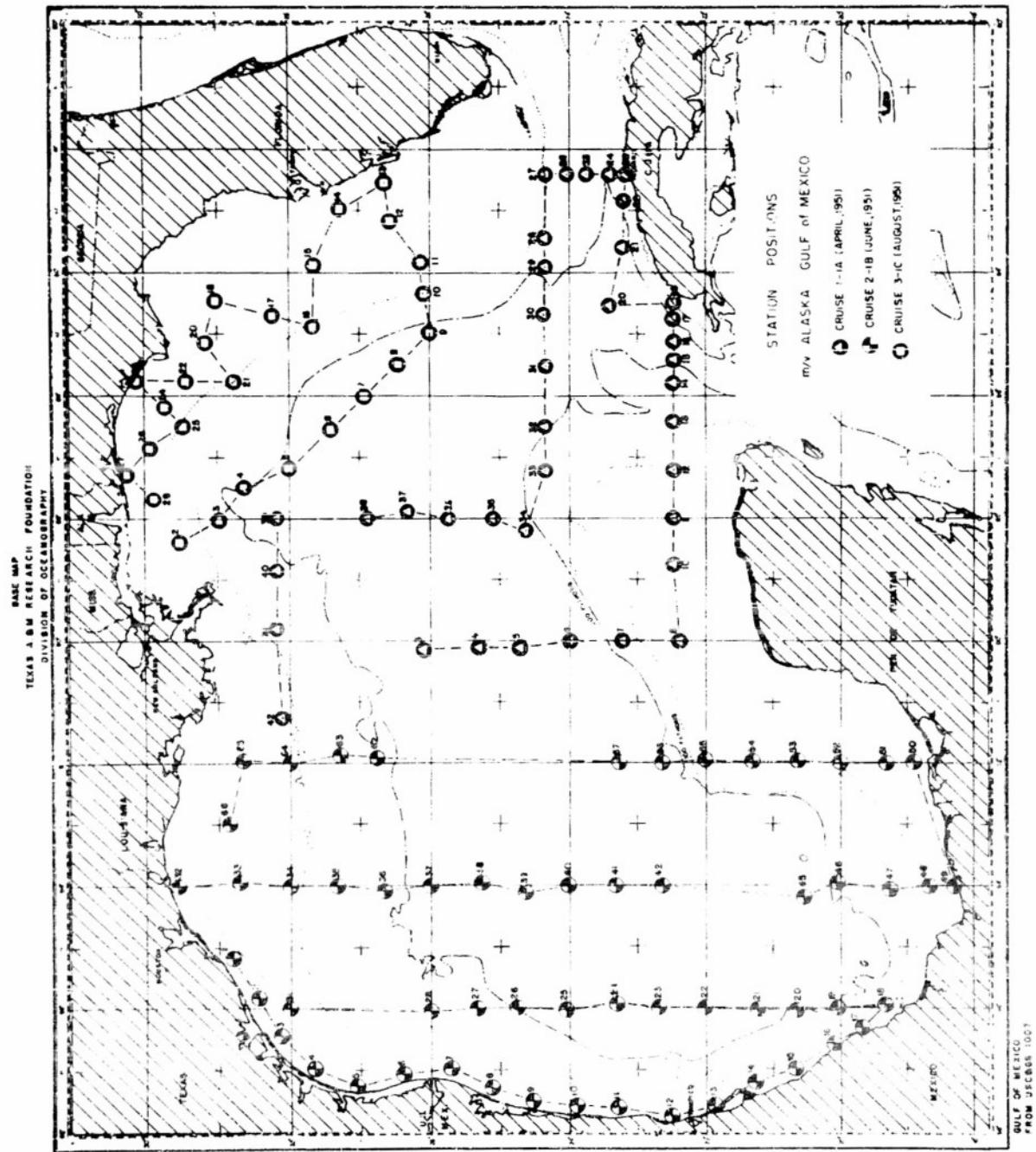


FIGURE 1

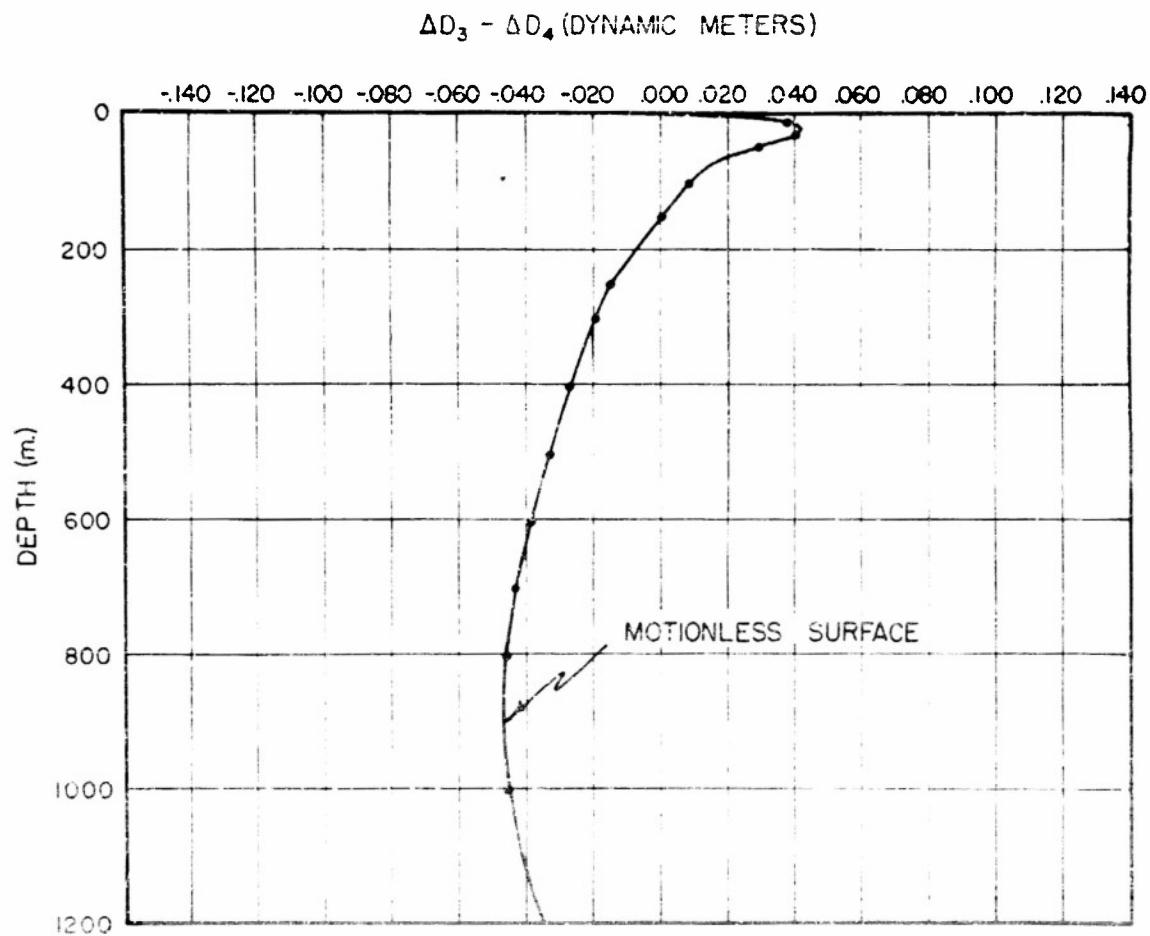
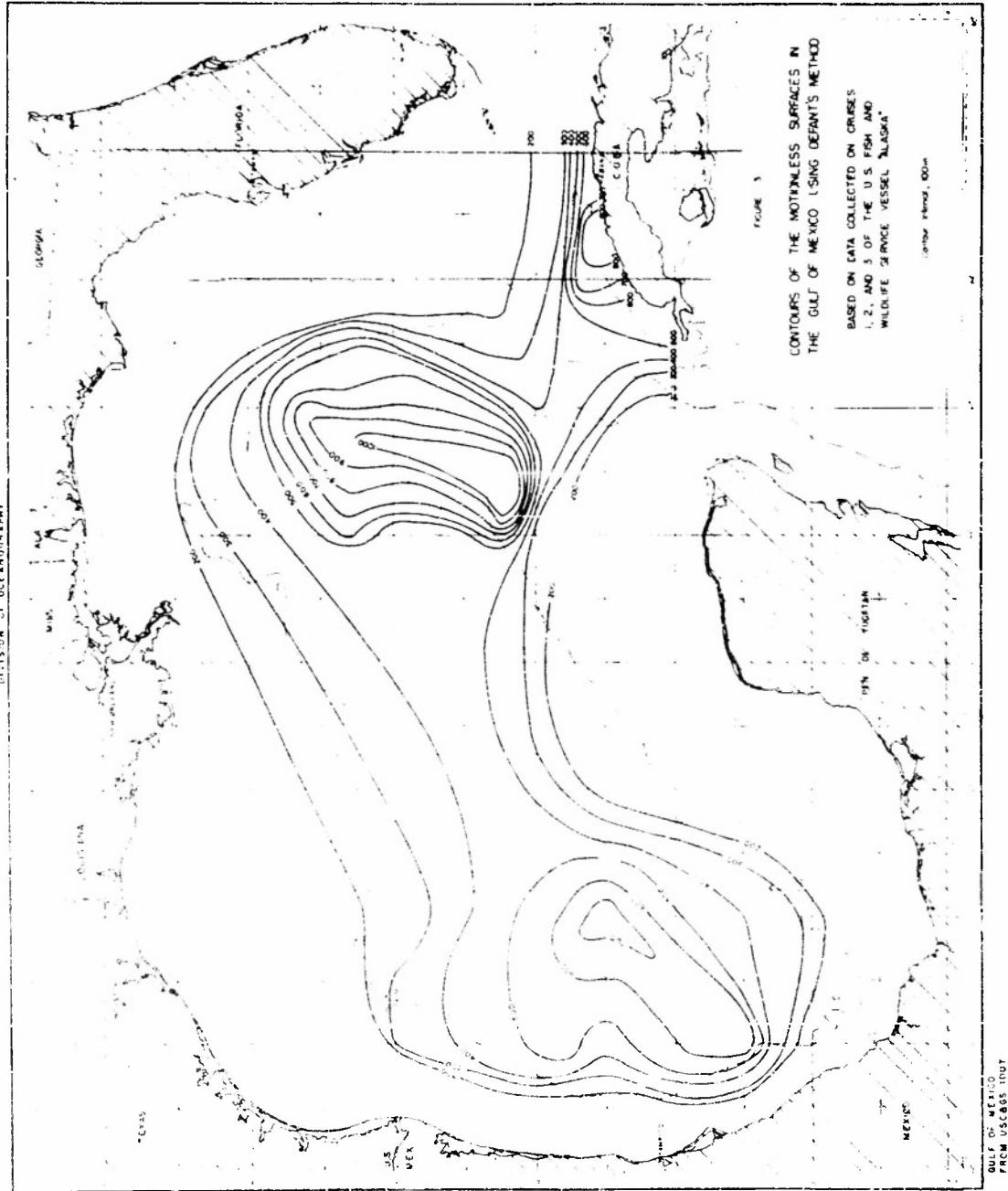
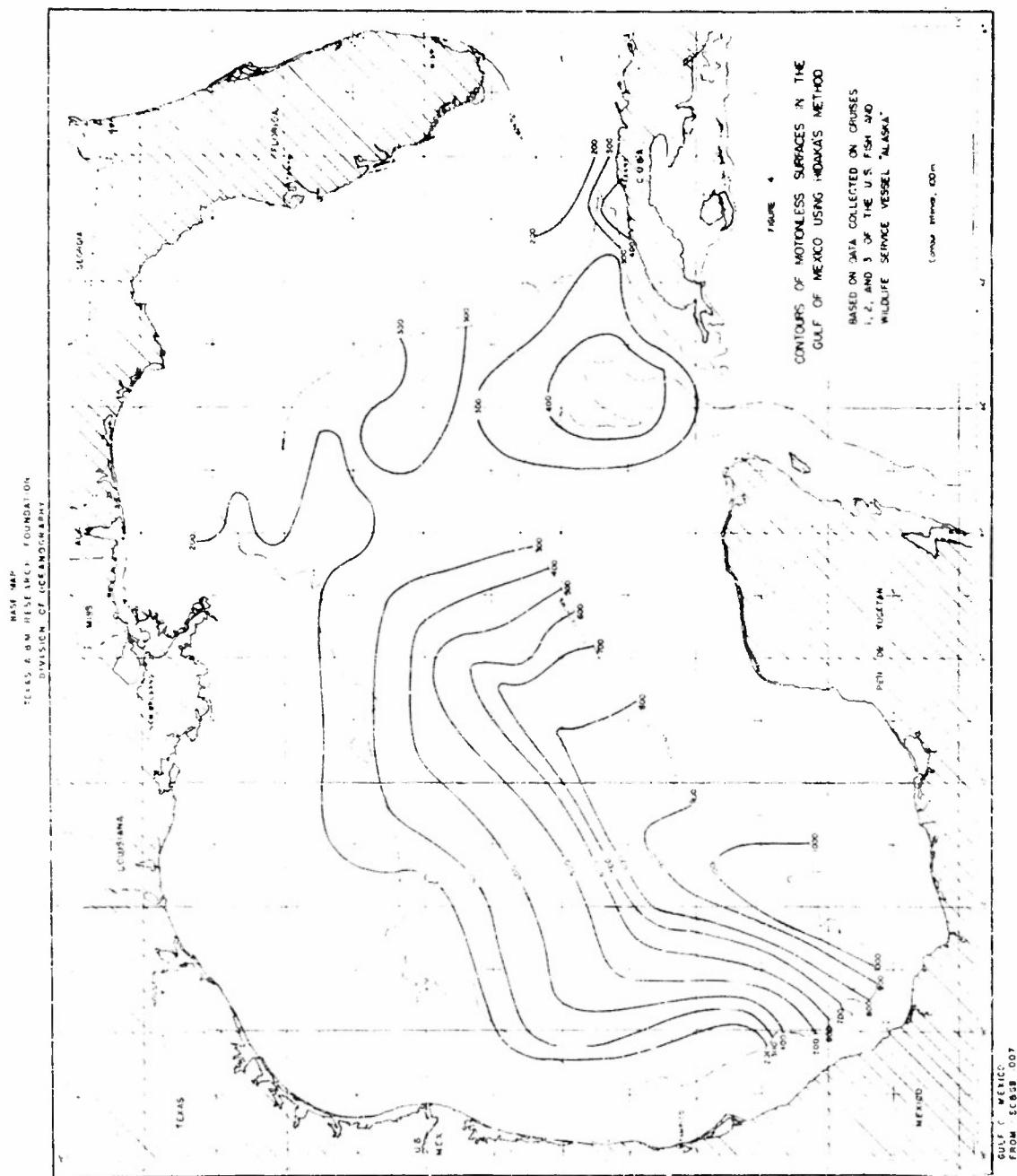


FIGURE 2

DIFFERENCES BETWEEN DYNAMIC DEPTH
ANOMALIES FROM THE SURFACE TO
EACH STANDARD PRESSURE SURFACE
FOR STATIONS 3 AND 4, CRUISE 3.

DATA MAP
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